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The Environmental Kuznets Curve for Deforestation in Indonesia

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Abstract

This study provides empirical findings on the relationship between deforestation and income in 32 provinces in Indonesia. To enrich the discussion on deforestation, this study investigates the impact of the factors of population, roundwood production, land area, and main crop production on deforestation. The selected main crops in Indonesia are oil palm, coffee, coconut, rubber, and cacao. The results confirm the existence of the EKC relationship between deforestation and income in Indonesia. The study also finds that oil palm production positively affects tree cover loss, but the production of natural rubber has the opposite impact on deforestation.

Keywords: Indonesia; deforestation; tree cover loss; EKC; agriculture

JEL classifications: O44; Q15; Q56

1. Introduction

Over the last couple of years, Indonesia has experienced relatively stable economic growth. In 2018, the growth slightly increases by 0.10% from 5.07% in 2017 (Economic Report on Indonesia 2018). Furthermore, the growth apparently emerges across the country, particularly in the eastern region such as Maluku and Papua where the growth increases higher than several regions in the west part such as Sumatera and Java. In terms of improving environmental quality, the government of Indonesia pays more attention to this sector by allocating a slightly greater budget to protect and restore the environment, approximately USD863 million in 2016 and increasing to USD1.1 billion in 2018 (Statistics Indonesia 2018). Moreover, the growth in gross domestic product of industries that use natural resources directly such as agriculture, fishery, and forestry, has a variation in trend. Both agriculture and fishery industries have a decline in the growth rate, while in forestry sector, the growth rises considerably to 2.31% in 2017 from 0.58% in 2014 (Statistics Indonesia 2018).

Indonesia had about 118 million ha (hectare) of tropical forest in 1990 or 65.4% of the land area (World Bank 2019a,b). However, in 26 years (data 2016), the area of forest cover of this country has declined to about 49.86% of the land area, even though the annual deforestation decreased from 1900 ha per year in 1990 to 500 ha per year in 2010 (FAO 2014,2015; World Bank 2019a,b). According to FAO (2014,2015), forest depletion in Indonesia is caused by land conversion to other land uses (deforestation) and forest degradation or forest quality decline. Particularly, both are caused by the intensification of timber concession for agricultural and mining activities, plantations, and transmigration (Ministry of Environment and Forestry Indonesia 2018). In addition, unsustainable forest management, illegal logging, encroachment and illegal occupation within forest areas, and forest fires are several other factors that have an effect on deforestation and forest degradation. These issues then become challenges

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for the Government of Indonesia to achieve sustainability, not only in the economic growth but also in its natural resources, particularly in the forestry sector.

This paper provides a study on the relationship between environmental quality and economic growth in Indonesia, particularly in the forestry sector. In section 2, previous studies regarding the relationship between environmental quality and economic growth in several countries, including Indonesia, will be summarized. Furthermore, empirical findings on deforestation and economic growth as well as the impact of deforestation and selected policies regarding deforestation in Indonesia will be discussed in section 3. Datasets and model selection will be presented in section 4. In section 5, the results will be discussed and section 6 as the last section concludes this study.

2. Literature Review

2.1. The Relationship Between Environmental Quality and Economic Growth

One of the tools commonly used to describe the relationship between economic growth and environmental quality is the Environmental Kuznets Curve (EKC). It has resemblance to Kuznets's postulate of inequality in income distribution and economic growth. EKC elucidates that an increase in per capita income is initially accompanied by worsening environmental conditions to a certain point (the early stage), but then followed by an improvement in environmental quality as a more prosperous society demands a better environmental quality (Hussen 2004). The core policy implication of this postulate is environmentally-degrading development is sustainable supposing the growth of the development reaches the certain point of environmental restoration and the process of development does not exceed the ecological carrying capacity (Bhattarai & Hammig 2001). In other words, even though certain development may deteriorate the environment in the early stage of growth, the government still should provide policies and institutions in environmental programs, particularly to restore the degradation at this stage (Bhattarai & Hammig 2001).

The linkage has been investigated extensively by numerous researchers since 1990s with various environmental indicators. For instance, Grossman & Krueger (1991,1995) find that there is no evidence related to environmental quality that deteriorates steadily with economic growth in the United States of America and Mexico. They use per capita income and environmental indicators such as urban air pollution, oxygen quality in river basins, faecal contamination in river basins, and heavy metal contamination in river basins. Selden & Song (1994) conduct their research on the relationship between per capita emissions, real GDP per capita, and population density across countries and time and reach the similar conclusion with the previous researchers. This study exhibits an inverted U-shaped relationship, suggesting that emissions will decrease in the significantly long run. Barbier (2004) studies the impact of the rate of water utilization on economic growth. The result confirms an inverted-U shaped in the EKC hypothesis (this study analyzed the data of 163 countries). However, a study conducted by Katz (2015) shows that only some of the data confirms the EKC hypothesis and it is because the research results largely depend on the selection of datasets and statistical technique (this study used 30 OECD countries and states in the United States of America).

A meta-analysis study by Angelsen & Kaimowitz (1999) seems to question the results of studies using various economic models in analyzing the relationship between economic growth and environmental quality, particularly the EKC model in analyzing the causes of deforestation. It is due to the weak methodology and low-quality data (Angelsen & Kaimowitz 1999). However, Choumert, Motel & Dakpo (2013) argue that the EKC hypothesis still will be used and useful in estimating the causes of deforestation until theoretical alternatives are provided.

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Regarding studies on EKC in Indonesia, many researchers pay attention to a certain environmental indicators such as carbon dioxide emission. Sasana & Aminata (2019) conduct a study on how economic growth, energy subsidies, total use of primary energy, renewable energy, economic globalization, and population affect the amount of carbon dioxide emissions in Indonesia. They conclude that EKC hypothesis does not exist in Indonesia in the long run. It means that economic growth in Indonesia seems unsustainable, leading to an increase in carbon dioxide emissions. Their finding is supported by other researchers such as Saboori, Sulaiman & Mohammad (2012). Meanwhile, Sugiawan & Managi (2016) find that the EKC relationship between economic growth and carbon dioxide emissions holds for the case of Indonesia with an estimated turning point of USD7,729 per capita. In addition, this study considers the importance of renewable energy in electricity production that reduces the amount of carbon dioxide emissions. Moreover, Alam et al. (2016) as well as Oktavilia & Firmansyah (2016) find the same conclusion as Sugiawan & Managi (2016) for the case of Indonesia.

2.2. Empirical Findings on Deforestation and Economic Growth

FAO (2001) defines deforestation as "the conversion of forest to another land use or the long-term reduction of the tree canopy cover below the minimum 10 percent threshold." The conversion can be in the form of agriculture, urban development, or an unintentional consequence of uncontrolled grazing (Tejaswi 2007). Angelsen & Kaimowitz (1999) find that tropical deforestation is driven by road building, increasing agricultural prices, lower wages, and lower employment in the non-farm sector. Yet, how those causes affect deforestation is unspecified. In addition, several macroeconomic factors such as population growth, poverty reduction, national income, economic growth, and foreign debt have an ambiguous relationship with deforestation.

By employing cross-country data, Barbier & Burgess (2001) analyze how land use affects tropical forest cover. This study suggests that the pattern of agricultural development in the selected countries apparently has an impact on the growth of land area for agricultural activities. This growth seems to be the main cause of deforestation in those tropical countries. In addition, population growth and institutional factors tend to have an important role in reducing tropical forest cover. Furthermore, this study finds that the EKC relationship does not always exist, depending on regions.

In analyzing the issue of deforestation, using different indicators to measure governance apparently will affect the outcomes of the study (Wehkamp et al. 2018). Studies using governance measurements such as environmental policy, ownership rights, and the presence of environmental non-government organizations and law enforcement, suggest that better governance contributes to reduced deforestation. On the other hand, studies that analyze other governance indicators, for example democracy and rights, find the opposite relationship. Interestingly, Bhattarai & Hammig (2001) find that countries with high restrictions on political freedom such as Bhutan and China have more reforestation programs and actively reduce deforestation rates. Their study also shows that institutional factors such as political rights and civil liberty have a significant impact on deforestation in Africa and Latin America where an improvement in institutional and political factors leads to a reduced deforestation rate and better nature conservation. This study suggests that institutional and political indicators are relatively more important in explaining the causes of deforestation compared to macroeconomic factors only. It is because institutional and political factors have a powerful influence on the design of policy to address environmental protection.

Several researchers are also concerned about how flat the EKC is and its relationship with institutional improvement. It means that certain development may reduce degradation of the environment even during the early stage of development. Bhattarai

& Hammig (2001) suggest that enhancing socio-political institutions may lead to a flatter EKC in analyzing deforestation. This finding is corroborated by Culas (2007) who studies deforestation across countries in Latin America, Africa, and Asia. He suggests that an institutional improvement, particularly in property rights and environmental policies, leads to a flatter EKC that means that the deforestation rate can be reduced without halting the development.

In terms of the causes of deforestation in Indonesia, one of the earliest studies about this issue is conducted by Angelsen (1995). This study focuses on how agricultural expansion affects deforestation in Sumatra. Angelsen (1995) argues that the agricultural shifting is affected solely by changes in land rent that lead to deforestation. In addition, this study finds that technical progress (such as intensification programs) as well as road and infrastructure improvements, contribute to an increase in the forest clearing rate. However, the agricultural shifting has positive characteristics, particularly when rice cultivation is shifted to rubber plantation because it is closer to have a forest function, thus more sustainable and contributing a greater income than rice-based cultivation for smallholders. Even though rubber plantation is potential sustainable intensification, the incentives for this plantation to intensify are limited because people tend to secure rights to new land rather than building new rubber plantation in the cleared forest. The most important part of this study is government projects such as transmigration, new plantation, logging, and mining that have a multiplier effect on deforestation: the expected future land scarcity leads to a race on securing rights over the land that is already cleared. Securing new land through land markets involving a large private export sector is believed to affect deforestation in Indonesia. Krishna et al. (2017) find that this sector that holds legal rights from the government is a prominent driver in increasing the rate of deforestation and forest land appropriation in Jambi Province. On the contrary, this study shows that land market transactions by smallholder communities have no significant effect on deforestation. It is noteworthy that the findings by Angelsen (1995) and Krishna et al. (2017) should be part of consideration for the government in designing environmental policy that directly focuses on reducing the deforestation rate.

Sunderlin & Resosudarmo (1996) in their review also find that shifting cultivation contributes to decreasing forest cover. Other factors that have strong relationship with deforestation discussed in this study include the production of tree crops by smallholders such as rubber, oil palm, coffee, and coconut plantations. Moreover, logging and the timber industry, transmigration activities, and population density are several other factors that tend to have high correlation with deforestation in Indonesia. Yet, Barbie et al. (1995) argue that the timber industry is not the major factor of tropical forest cover loss in Indonesia. Illegal logging is another important driver of the forestry problem in Indonesia (Palmer 2001). Palmer (2001) argues that illegal logging occurs due to market and government failures such as corruption in government institutions. Furthermore, transmigration (one of the historical projects of the Government of Indonesia) and population growth also play an important role in deforestation (Sunderlin & Resosudarmo 1996,1999; Darmawan, Klasen & Nuryartono 2016).

Among the numerous studies about deforestation in Indonesia, it seems only one study applying EKC hypothesis in analyzing the relationship between deforestation and economic growth. The study is conducted by Waluyo & Terawaki (2016). By using national level data (1962 to 2007) of annual deforestation rate, real GDP per capita, population growth, rural population, agricultural index, agricultural land area, roundwood production, and export of forest products, this study finds that the hypothesis of EKC holds for Indonesia. It means that the economy of Indonesia deteriorates forest cover in the initial stage of development and the deforestation tends to decrease as the income reaches a turning point. Another finding of this study is that the relationship between deforestation rate and proxies such as rural population, agricultural index, and

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roundwood production is negatively significant.

Yet, studies on deforestation and economic growth that use EKC hypothesis with Indonesian data seems to be limited. To extend the discussion, this study examines the impact of economic growth on the forestry sector in Indonesia by employing provincial level data. Tree cover loss is used to represent environmental indicators. Furthermore, factors -as suggested by previous studies- that apparently influence deforestation, are used to analyze the EKC hypothesis. The factors are real per capita income, population growth, roundwood production, land for agriculture purposes, and agriculture production. In addition, this study employs data on five main plantation crop productions (oil palm, rubber, coffee, coconut, and cocoa) in Indonesia to enrich the discussion on deforestation and economic growth in this country.

2.3. Impact of Deforestation

Forest is a multifunctional system having productive, protective, and socio-economic functions (FAO 2001). Forest provides timber and non-timber products, such as fuelwood, food, medicine, water, and numerous genetic resources (Perman et al. 2003). Additionally, forest as an ecosystem supplies important services, for example air pollution reduction, local climate improvement, nutrient cycling, soil formation, home for biodiversity and human, watershed maintenance, and a place for leisure activities (Perman et al. 2003). The decline in forest functions then leads to several significant potential problems: disturbing the local or regional climate that affects water cycle, threatening the life of biodiversity, and affecting human health. Furthermore, the decline in forest quality also might potentially cause conflicts between wildlife and human activities and disturb the settlements of indigenous people. The following discussion is about how deforestation or forest degradation might decrease forest quality and affect the life either within or outside the forest.

Swann et al. (2015) find that shifting natural forest ecosystem into agricultural crops in the Amazon rainforest is estimated to lead to a warmer and drier climate in South America. Moreover, their study does not suggest significant reduction in precipitation. It means that the link between eco and climate system is uncertain, supporting a study by Pitman & Lorenz (2016). Another study by Hu, Huang & Cherubini (2019) also finds that deforestation causes a drier climate and a more severe cold extremes in Europe. In contrast, afforestation creates a wetter climate, and it mitigates a highly potential incidence of the cold extremes (Hu, Huang & Cherubini, 2019). In addition, this study highlights that the estimated climate in the analysis is stronger at the local level than the regional level. Evidently, shifting in climate due to deforestation affects the hydrological system. A simulation study run by Gaertner et al. (2001) shows that deforestation leads to a reduction in evaporation during spring and summer in several regions in the western Mediterranean area. Moreover, in late spring and summer, precipitation tends to decrease. Delire et al. (2001) suggest that the precipitation over deforested land drops by 9% due to the extremely rapid rate of deforestation in the Indonesian Archipelago. In North Korea, deforestation causes a decrease in water supply as water demand from agricultural sector is increasing (Lim et al. 2019). Deforestation also leads to a declining water balance in this country. Additionally, this study compares North Korea with its neighbor country South Korea and finds that South Korea has an improvement in water balance as this country has been working continuously on afforestation.

Deforestation is threatening the life of biodiversity. According to a study conducted by Fayle et al. (2010), the total ant species decreases by 64% due to the expansion of oil palm plantation into the rainforest in Sabah, Malaysia. Furthermore, the number of mammal biodiversity seems to be decreasing in areas close to roads built for agricultural expansion purposes in Peninsular Malaysia (Adila et al. 2017). The decline in the quality of the savannah that has similar function to forest for biodiversity, may lead to the depletion of the amount of biodiversity. In the natural savannah of Columbian Llanos, the total bird species richness is declining as the oil palm estates are growing (López-Ricaurte et al. 2017). The number of Sumatran elephants has decreased by more than half since 1985 due to changes in land use, where in present day, there are less than 3000 Sumatran elephants living in the wild (Hang & Lyons 2019). The same trend goes to the number of Sumatran tigers that are less than 400 tigers left in the wild (Bell 2014).

Furthermore, deforestation may affect human health through some infectious diseases. One of the earliest studies about the relationship between deforestation and its effect on diseases is conducted by Walsh, Molyneux & Birley (1993). They find that vector-borne diseases have been affected by the loss of natural tropical forests. Arbovirus, malaria, the leishmaniases, filariases, Chagas disease, and schistosomiasis are several examples of viral and parasitic infections. Moreover, this study finds that deforestation creates new homes for *Anopheles darlingi* mosquitoes associated with malaria epidemics in South America. In addition, in South East Asia and West Africa, tropical forest clearance has correlation with the malaria incidence. Climate change (to a warmer condition) due to deforestation leads to the development and survival of two larvae of Anopheles mosquito species in East African highlands (Afrane, Githeko & Yan 2012). Additionally, deforestation may cause an increase in the survival of adult mosquitoes. In Indonesia, deforestation between 2001 and 2008 has caused additional 360,000–880,000 malaria infections (Garg 2014). The similar finding is suggested by Santos & Almeida (2018) who study the impact of deforestation on malaria infections in the Brazilian Amazon. Specifically, Patz at al. (2004) list the following infectious diseases that are highly correlated with landscape change and causing diseases not only on human but also on other creatures: with vector-borne agents causing malaria, dengue, Lyme disease, yellow fever, and others. In soil, diseases such as melioidosis, anthrax, hookworm, and coccidioidomycosis may occur. Water-borne agents cause schistosomiasis, cholera, shigellosis, rotavirus, salmonellosis, leptospirosis, and cryptosporidiosis. Asthma, tuberculosis, and influenza are several diseases with human as their agents.

Furthermore, the decline in forest quality also might potentially cause conflicts between wildlife and human activities. The competition between human and wildlife for resources and living space is the prominent factor of human-wildlife conflicts globally (Lamarque et al. 2009). Additionally, the gradual loss of wildlife habitat exacerbates and increases the incidence of the conflicts. It is because the range of wildlife becomes more fragmented and their coverage to forage becomes smaller. Deforestation is related to increasing incidents with elephants in India (Puyravaud et al. 2019). Changing in their habitat makes these mammals destroy crops and become a threat to human lives. In Indonesia, the following critically endangered wildlife have been conflicting with human activities due to tree cover loss: Sumatran tigers, Sumatran elephants, orangutans, and leopards. In Sumatra, tigers get closer to human settlements as the result of habitat loss due to deforestation (Bell 2014). These solitary animals are most probably to eat livestock and considered a threat to human (sometimes ending with the death of those animals, killed by humans). The similar condition occurs to Sumatra elephants, orangutans in Sumatra and Kalimantan, and leopards in West Java (Hewson 2015; Hang & Lyons 2019; Qomariah 2018; Gunawan et al. 2017).

2.4. Policies to Reduce the Deforestation Rate in Indonesia

Indonesia has implemented several policies to reduce the rate of deforestation. They are REDD+ scheme, timber legality assurance system (timber certification), and forestry stewardship certification as well as efforts to improve law enforcement and property rights. The last type of policy is integrated within the remaining policies.

REDD or *Reducing Emissions from Deforestation and Forest Degradation* is a scheme to compensate (by financial value) developing countries in order to

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reduce the deforestation rate and forest degradation by a certain measurement (Swedish Society for Nature Conservation 2013). This scheme was proposed by a coalition of countries that own a large area of tropical forest in 2005. Two years later, in 2007, the scheme became REDD+, focusing not only on carbon issue but also conservation, sustainable forest management, and enhancement of forest carbon stocks. In the same year, the Government of Indonesia has committed to implement this scheme by reducing emissions from deforestation and forest degradation by 26% of the usual emission level of its business by 2020 with self-funding and 41% of international support (Indrarto et al. 2012). In implementing this scheme, the Government of Indonesia has started several actions such as building a partnership with the Government of Norway by signing a Letter of Intent to initiate demonstration activities and developing a National Action Plan on Greenhouse Gases as well as a National REDD+ Strategy (Indrarto et al. 2012). Since the early year of the application of REDD+ scheme until now, it has faced several noticeably challenges. Indonesia apparently has weaknesses in managing forest, particularly in terms of institutions and capacity, administration in licensing rules, and law enforcement (Indrarto et al. 2012; Mulyani & Jepson 2013). Moreover, conflicts over land tenure and unclear property right issues are considered as the main challenges in implementing this scheme (Sunderlin et al. 2018). Enrici & Hubacek (2018) find that challenges in implementing REDD+ in Indonesia include inadequate funding opportunities, rent-seeking problems such as corruption, and poor planning leading to the condition of less community participation. The issue of corruption is also highlighted by Mulyani & Jepson (2013) in REDD+ discussion. In addition, their study suggests that REDD+ seems to be complex to implement. Furthermore, there is uncertainty regarding decisions on REDD+ as a tool for developed countries. However, after a decade of implementing REDD+ scheme, Indonesia has apparently succeeded in reducing the rate of deforestation in 2017, thus preventing 4.8 million tons of carbon dioxide equivalent that might release supposing Indonesia was still under business as usual (Jong 2019). In addition, as part of the partnership with the Government of Norway, Indonesia will receive the first payment of US $1 billion for the success in reducing the deforestation rate.

One of the commitments of the Government of Indonesia in addressing deforestation is improving the rule of law and enhancing the quality of administration and institutions. For example, establishing timber legality assurance system (SVLK) and forestry stewardship council certification. SVLK has been developed by the Government of Indonesia since 2013 as part of the Voluntary Partnership Agreement (VPA) that is the core part of EU Forest Law Enforcement, Governance and Trade (FLEGT) action plan (Obidzinski et al. 2014). The aim of this certification is to ensure the legality of all timber and timber products that will be exported to the EU countries in order to reduce illegal logging. SVLK verification shows significant progress in large and medium timber companies, yet in the small-scale enterprises, SVLK remains slow (Obidzinski et al. 2014). According to a study conducted by Obidzinski et al. (2014), the implementation of SVLK is challenged by the costs of verification and surveillance, lack of awareness and understanding about SVLK and compliance requirements. Furthermore, Indonesia lacks accredited timber legality verification bodies to conduct audits. Forestry stewardship has been established to support good governance in forestry management. Indonesia has several voluntary third parties of forestry stewardship, such as the Forest Stewardship Council (FSC) that is the only stewardship council involving international civil society organizations (Klassen, Romero & Putz 2014). In implementing this certification scheme, FSC deals with unclear land tenure and inconsistent forest regulations.

Reducing deforestation is a global mission. Several researchers suggest a number of valuable policies to deal with this issue. In reducing deforestation, several important policies should be considered, as suggested by Angelsen (2010). The suggested policies are reducing the rent of extensive agriculture, increasing the rent of extractive or protective forest, and establishing community forest management. Moreover, protected areas should be established in order to limit forest conversion into other land uses. Observed from the supply side, public-private companies are encouraged to improve the effectiveness of supply-chain initiative to reduce deforestation (Lambin et al. 2018). Furthermore, Brazil has achieved success in reducing deforestation by implementing several influential policies (Boucher, Roquemore & Fitzhugh 2013). This tropical country applies the following policies to deal with deforestation issue: government policies and enforcement actions by prosecutors, both at the federal and state levels; the incentive created by Norway's pledge of up to US $1 billion in results-based compensation through the Amazon Fund; the strong and concerted pressure exerted by Brazilian civil society on the Government and the soy and beef industries; the positive response from those industries results in the 2009 soy and 2009 beef moratoria (Boucher, Roquemore & Fitzhugh 2013).

3. Method

3.1. Datasets

In this study, a balance panel data was employed to capture a wider insight. The relationship between tree cover loss and real income per capita from 2013-2016 in 32 Provinces in Indonesia was analyzed with the EKC hypothesis. The list of selected provinces is provided in Table 5 in Appendix. The data for tree cover loss were obtained from Global Forest Watch and the data for all explanatory variables were obtained from Statistics Indonesia. Information about the selected explanatory variables and their relationship with tree cover loss is summarized in Table 1.

Tree cover loss data were obtained from Global Forest Watch, an online platform for monitoring the most recent forest status across the globe (Global Forest Watch 2019). This platform was initiated by the World Resources Institute (WRI) in partnership with several reputable organizations such as the University of Maryland by using a supervised learning algorithm. The data include tree cover, natural forest, and primary forest. Interestingly, shrubs, rubber and palm trees, as well as natural forests are included to be observed. The data were measured by using the complete removal of tree cover canopy at 30 by 30-meter resolution in one year of data from January to December. Furthermore, in producing the data, several factors that lead to tree cover reduction were considered. For example, timber harvesting, deforestation, and natural causes such as disease or storm damage and fire, either induced by nature or human activities (Goldman, Said & Hamzah 2018). Therefore, tree cover loss data have broader coverage to capture important types of loss in the forestry sector. This study used tree cover loss data (in thousand hectares) at first sub-national level or provincial level with a canopy cover threshold of 30%.

As suggested by previous studies, real income per capita and the squared term of real income per capita were used to capture the existence of EKC relationship (Selden & Song 1994; Bhattarai & Hummig 2001; Taguchi 2012; Waluyo & Terawaki 2016). The expected sign is positive for income per capita and negative for the quadratic term or $\beta_1 > 0$ and $\beta_2 < 0$ (Selden & Song 1994). Furthermore, this study employed several other important factors that affect forest cover: population growth, roundwood production, agriculture land area, agriculture production, and production of the main crops in Indonesia (oil palm, coffee, coconut, rubber, and cacao). Numerous studies suggest that population growth has a positive impact on deforestation (Sunderlin & Resosudarmo 1996,1999; Bhattarai & Hammig 2001; Barbier & Burgess 2001; Darmawan, Klasen & Nuryartono 2016). However, Angelsen & Kaimowitz (1999) argue that population growth is ambiguously related to deforestation.

Furthermore, roundwood production data were used to represent the forestry sector. As Sunderlin & Resosudarmo (1996) suggest, the logging and timber industry has a high correlation with deforesta-

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Table 1. The Definitions of Explanatory Variables and the Expected Relationship with Tree Cover Loss

Explanatory variable	Unit	Descriptions	Expected Sign
GDP	Rupiah (thousands)	Real GDP per capita 2010	Positive
GDP Squared			Negative
Population growth	%	Annual percentage of population growth (projected data)	Positive
Roundwood production	Cubic meter (thousands)	Annual production of roundwood	Positive
Agriculture land area	Hectare (thousands)	Total annual agriculture land area of 5 main plantations (oil palm, coffee, coconut, rubber, and cacao)	Positive
Agricultural production	Ton (thousands)	Total annual production of 5 main crops (oil palm, coffee, coconut, rubber, and cacao)	Positive
Oil palm Production	Ton (thousands)	Total annual production of oil palm plantation	Positive
Coffee production	Ton (thousands)	Total annual production of coffee plantation	Positive
Coconut production	Ton (thousands)	Total annual production of coconut plantation	Positive
Rubber production	Ton (thousands)	Total annual production of rubber plantation	Positive
Cacao production	Ton (thousands)	Total annual production of cacao plantation	Positive

tion in Indonesia. In addition, Barbier et al. (1995) find that timber production is not the major factor regarding deforestation in the country. However, a study by Waluyo & Terawaki (2016) shows that timber production has a negative relationship with deforestation in Indonesia. The roundwood production data for this study consist of main timber production such as acacia, teak, shorea, albizzia, mixed wood, and others (as listed by Statistics of Forestry Production Report by Statistics Indonesia (various years)).

Observed from the agricultural sector, representing technological change, this study focuses on how the expansion of the main plantations affects forest cover, particularly land area and the production of the following plantations: oil palm, coffee, coconut, rubber, and cacao. In fact, Indonesia owns one of the largest tropical forests in the world and at the same time is also one of the largest producers of those crops. Indonesia produces 50.31% of the total production of oil palm in the world (FAO 2019a). This fact drives Indonesia to work more on how to preserve the forest frequently targeted as the prospective land for plantations. Table 2 provides the proportion of the main crop production of the total world production. The production of these crops, specifically from smallholder plantations, has a strong relationship with forest cover decline (Sunderlin & Resosudarmo 1996). However, this study employed agriculture land area and production data from mixed owners: smallholders, estates, and state-owned plantations.

Table 2. Main Crops in Indonesia

Crop	Percentage of World total production
Oil palm	50.31% (1st largest producer)
Coffee	7.25% (4th largest producer)
Coconut	31.23% (1st largest producer)
Rubber	25.46% (2nd largest producer)
Cocoa	12.68% (3rd largest producer)

Note: Data were extracted from FAOSTAT (FAO 2019b). Oil palm data were obtained from 2013 data, while the production data of other crops were obtained from 2017 data.

3.2. Model Selection

This study employed a reduced form model commonly used in validating EKC hypothesis. The model allows measuring direct and indirect linkages between income and environmental quality (List & Gallet 1999). There are several previous studies that confirm the model, such as Selden & Song (1994), Grossman & Krueger (1991,1995), List & Gallet (1999), Katz (2008), and Bhattarai & Hummig (2001). Furthermore, this study adopted a model from a study by Bhattarai & Hummig (2001) that focus on deforestation and economic growth. The model is as follows:

$$\begin{aligned}\mathrm{TCL_{it}} &= \alpha_\mathrm{i} + \beta_1\mathrm{GDP_{it}} + \beta_2\mathrm{GDP^2_{it}} + \beta_3\mathrm{P_{it}} \\ &\quad + \beta_4\mathrm{RWOOD_{it}} + \beta_5\mathrm{AGL_{it}} \\ &\quad + \beta_6\mathrm{AGPro_{it}} + \mathrm{u_{it}} \qquad (1)\end{aligned}$$

where, $\mathrm{i} = 1, \ldots, \mathrm{n}$ is provinces and $\mathrm{t} = $ year; $\mathrm{TCL_{it}}$ represents tree cover loss; α_i is the intercept term; $\beta\mathrm{s}$ tells about the coefficients to be estimated in the model; $\mathrm{GDP_{it}}$ is Gross Domestic Product per capita; $\mathrm{P_{it}}$ is the population growth; $\mathrm{RWOOD_{it}}$ is production of selected timber; $\mathrm{AGL_{it}}$ is the agricultural areas of the main crops; AGPro is the production of the main crops; and $\mathrm{u_{it}}$ is the error term. Summary statistics of model 1 are provided in Table 6 in Appendix.

In order to capture a wider insight on the production of the main crops related to forest cover, another model is estimated:

$$\begin{aligned}\mathrm{TCLit} &= \alpha_\mathrm{i} + \beta_1\mathrm{GDP_{it}} + \beta_2\mathrm{GDP^2_{it}} + +\beta_3\mathrm{P_{it}} \\ &\quad +\beta_4\mathrm{RWOOD_{it}} + \beta_5\mathrm{OPPro_{it}} \\ &\quad +\beta_6\mathrm{COFFPro_{it}} + \beta_7\mathrm{CONUTPro_{it}} \\ &\quad +\beta_8\mathrm{RUBPro_{it}} + \beta_9\mathrm{COCOPro_{it}} \\ &\quad +\mathrm{u_{it}} \qquad (2)\end{aligned}$$

where, $\mathrm{i} = 1, \ldots, \mathrm{n}$ is provinces and $\mathrm{t} = $ year; $\mathrm{TCL_{it}}$ represents tree cover loss; α_i is the intercept term; $\beta\mathrm{s}$ tells about the coefficients to be estimated in the model; $\mathrm{GDP_{it}}$ is Gross Domestic Product per capita; $\mathrm{P_{it}}$ is the population growth; $\mathrm{RWOOD_{it}}$ is production of selected timber; $\mathrm{OPPro_{it}}$ is production from oil palm plantation; $\mathrm{COFFPro_{it}}$ is production from coffee plantation; $\mathrm{CONUTPro_{it}}$ is production from coconut plantation; $\mathrm{RUBPro_{it}}$ is production from rubber plantation; and $\mathrm{COCOPro_{it}}$ is production from cacao plantation. Summary statistics of model 2 are provided in Table 7 in Appendix.

Furthermore, to accommodate an econometric theory in the panel data discussion, both models were tested for the simple pooled, the fixed effect model, and the random effect model. At the first stage, the standard F test was applied to decide which model is better between the simple common constant OLS method and the fixed effect model. The test shows that the latter is the appropriate model. Then, Hausman test was conducted to identify whether the individual effect of each province is correlated with the regressor or to decide whether the fixed effect model or the random effect model is appropriate for this study (Asteriou & Hall 2007). Subsequent to conducting Hausman test (either for model 1 or 2), the result suggests that the random effect is rejected at any level of significance, leading to a conclusion that the fixed effect remains appropriate for the model (either for model 1 or 2). Baltagi (2008) suggests that when the true model is the fixed effect, then the estimated parameters of OLS are biased and inconsistent because OLS excludes the individual dummies from the panel data despite their relevance. Thus, to resolve the problem, the weighted least square or generalized least square (GLS) and feasible GLS were used to estimate the chosen model (Bhattarai & Hummig 2001). In addition, a survey by Lieb (2003) on empirical evidence of the EKC shows that several studies use GLS because it is more appropriate to fix heteroscedasticity and autocorrelation.

4. Results and Analysis

4.1. Model (1)

The regression result shows that the EKC relationship exists in Indonesia. Income per capita term has a positive coefficient that is followed by a negative coefficient of income per capita squared term. Both terms are statistically significant. This result confirms that Indonesia deteriorates forest cover in the early stage of development and as income reaches a turning point, the tree cover loss tends to decline. The income turning point, $-\beta_1/2\beta_2$ (Selden & Song 1994), is at Rp89,955 (thousands) or about US$10,055. This estimated turning point is within the sample range: this point is less than the income of East Kalimantan (Rp125,385 (thousands)). Based on this finding, the deforestation level in East Kalimantan should be decreasing. However, the data shows that tree cover loss in this province has an unsteady trend; it increases significantly in 2014 up to 270,500 hectares from 179,330 hectares in 2013, then it declines to 231,724 hectares in 2015. The descriptive statistics summary shows that the mean for income per capita of the provinces in this

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study is Rp33,213 (thousands) or US$3,712. It suggests that the majority of the provinces in Indonesia is still at the early points of the upward sloping of the EKC curve where the tree cover loss is increasing. The regression result for the model is summarized in Table 3.

Table 3. Regression Result of Model 1

Explanatory variable	Coefficient
GDP	0.012
	(3.66)***
GDP Squared	-6.67e-08
	(2.50)**
Population growth	3.876
	(0.35)
Roundwood production	-0.011
	(1.82)**
Agriculture land area	0.062
	(0.91)
Agricultural production	0.05
	(2.71)***
Number of provinces	32
Number of observations	128
EKC turning point (in thousands Rupiah)	Rp89,955 or about US$10,055

Note: F statistic for this model is significant at 1%.
Absolute t-statistic values are in the parentheses
**Significant at 5%
***Significant at 1%

The production of roundwood and the crops from the main plantations has a statistically significant effect on tree cover loss in Indonesia. The negative sign of the coefficient of roundwood production suggests that tree cover loss decreases as timber production increases. This finding supports the result of the study conducted by Waluyo & Terawaki (2016). These researchers emphasize that the negative correlation between roundwood production and deforestation is due to the data on roundwood production that are the legally reported wood. They assume that these products are from the forest with sustainable management, therefore the products negatively affect forest cover. However, the crops production from the selected main plantations positively affects tree cover loss. This finding suggests that higher production in main crops leads to an increase in tree cover loss.

The coefficients of population growth and agriculture land area are positive, but statistically insignificant. As suggested by Angelsen & Kaimowitz (1999), several macroeconomic factors including population growth have an ambiguous relationship with deforestation. It seems agriculture land area is statistically insignificant because of the selected data in this study. The agriculture land area data here consist of the productive plantations, estates with young plants, and old or unproductive plantations. It appears that such data lead to a statistically insignificant result.

4.2. Model (2)

To capture a wider insight from the agricultural sector, this study employed data from 5 main crops in Indonesia. They are oil palm, coffee, coconut, rubber, and cacao. The regression result is provided in Table 4. Model 2 suggests that the coefficients of income per capita have the same sign as the result of model 1, either for GDP term or GDP squared term (positive and negative respectively). Both are statistically significant, confirming the existence of EKC relationship in Indonesia: where income positively affects tree cover loss at the early stage of development. The turning point from this model is at Rp81,453 (thousands) or about US$9,104, less than what model 1 suggests. Yet, supposing this turning point is compared to the mean of income per capita of the provinces, it leads to the same conclusion as the model 1: most provinces in Indonesia are currently at the phase where tree cover loss is increasing. Table 4 provides a summary of the result of model 2.

The coefficient of oil palm production is also positive and statistically significant in increasing tree cover loss. It suggests that an increase in oil palm production rises tree cover loss. This result supports the findings of Sunderlin & Resosudarmo (1996) and Austin et al. (2017). Interestingly, Austin et al. (2017) also find that the proportion of oil expansion encourages the decline in forest loss in 1995–2015. This finding suggests that the expansion of oil palm increasingly takes place in non-forest areas (Austin et al. 2017). It is noteworthy to highlight their finding since oil palm is one of the most controversial crops

Table 4. Regression Result of Model 2

Explanatory variable	Coefficient
GDP	0.013
	(3.91)***
GDP Squared	-7.98e-08
	(3.09)***
Population growth	-1.036
	(0.09)
Roundwood production	-0.015
	(3.07)***
Oil palm Production	0.054
	(3.27)***
Coffee production	-0.93
	(1.21)
Coconut production	0.71
	(1.19)
Rubber production	-0.63
	(2.37)**
Cacao production	0.11
	(0.21)
Number of provinces	32
Number of observations	128
EKC turning points (in thousands Rupiah)	Rp81,453.63 or about US$9,104

Note: F statistic for this model is significant at 1%.
Absolute t-statistic values are in the parentheses
**Significant at 5%
***Significant at 1%

across the globe recently with a reputation for forest loss entails.

Furthermore, this study finds that roundwood and rubber production negatively impacts tree cover loss and it is statistically significant. As suggested by the discussion in model 1, it seems that the roundwood production data originate from sustainably managed forest. Apparently, the negative coefficient of rubber production is caused by the fact that rubber plantation has a closer status to forest function (Angelsen 1995). In addition, rubber is considered as a sustainable agroforestry crop with a balanced and diversified system (Gouyon, De Foresta & Levang 1993). Thus, an increase in natural rubber production will not decrease tree cover.

Population growth has a negative coefficient in model 2 and it is statistically insignificant, the same result of which is obtained in model 1. The remaining variables: coffee, cocoa, and coconut production are statistically insignificant with negative coefficient for coffee production and positive for cocoa and coconut production. Bhattarai & Hammig (2001) highlight that deforestation literature is ambiguous in terms of the effect of agricultural technology (in which agriculture production is part of it) on the process of tropical deforestation.

5. Conclusion

The concept of EKC hypothesis is that environmental quality has an inverted-U relationship with economic growth. Focusing on deforestation, the results of this study suggest that the EKC relationship holds for Indonesia. As suggested by the concept, Indonesia during this study period had improved in environmental quality, particularly in reducing tree cover loss. Furthermore, this finding indicates that Indonesia is encouraged to ensure the sustainability of its improvement, either in environmental quality or economic growth.

The study also finds that the agricultural sector has two side of effects on tree cover loss: decreasing or increasing. Yet, both effects should be analyzed carefully since this sector provides livelihood for millions of people in Indonesia. Moreover, it is important to highlight another finding of this study from the forestry sector in Indonesia. The growth of gross domestic product of the industries from this sector rises considerably from year to year. Having a negative impact on tree cover loss, this sector seems to be sustainable for economic growth and environmental quality.

Due to data limitations, this study does not include institutional factors in the models. Yet, these prominent factors are suggested by numerous reputable researchers in analyzing deforestation. Institutional factors such as political rights and civil liberty, environmental policy, or forest governance should be considered in order to gain a deeper and wider insight in this discussion.

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Appendix

Table 5. Selected Provinces and Their Real Income in 2016 (constant to 2010)

Province	2016 income (thousands Rupiah)	in US$
Aceh	22835.29	2552.57
Bali	32689.09	3654.05
Bangka Belitung	34132.87	3815.43
Banten	31781.56	3552.60
Bengkulu	21039.84	2351.87
Gorontalo	20427.46	2283.42
Jambi	37728.80	4217.39
West Java	26923.51	3009.56
Central Java	24959.49	2790.02
East Java	35970.78	4020.88
West Kalimantan	24308.85	2717.29
South Kalimantan	28540.05	3190.26
Central Kalimantan	32899.58	3677.57
East Kalimantan	125385.53	14015.82
Riau Islands	80295.60	8975.59
Lampung	25568.57	2858.10
Maluku	15321.18	1712.63
North Maluku	18177.30	2031.89
West Nusa Tenggara	19305.79	2158.04
East Nusa Tenggara	11468.79	1282.00
Papua	44342.14	4956.64
West Papua	61242.01	6845.74
Riau	70569.36	7888.37
West Sulawesi	21067.91	2355.01
South Sulawesi	31302.53	3499.05
South East Sulawesi	30476.39	3406.71
North Sulawesi	30679.97	3429.46
West Sumatera	28164.93	3148.33
South Sumatera	32699.50	3655.21
North Sumatera	32885.09	3675.95
Yogyakarta	23565.68	2634.21

Table 6. Descriptive Statistics of the Variables of Model 1

Variable	Summary Statistics
Tree cover loss (thousands hectare)	
Mean	56.26
Standard Deviation	85.08
GDP per capita (thousands Rupiah)	
Mean	33213.97
Standard Deviation	22690.64
Population Growth (%)	
Mean	1.716
Standard Deviation	0.571
Round wood production (thousands meter cube)	
Mean	1.345.471
Standard Deviation	2.819.476
Agriculture land area (thousands hectare)	
Mean	655.75
Standard Deviation	708.09
Agriculture Production (thousands tons)	
Mean	1.181.091
Standard Deviation	1.786.321
Number of provinces	32
Number of observations	128

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Table 7. Descriptive Statistics of the Variables of Model 2

Variable	Summary Statistics
Tree cover loss (thousands hectare)	
Mean	56.26
Standard Deviation	85.08
GDP per capita (thousands Rupiah)	
Mean	33213.97
Standard Deviation	22690.64
Population Growth (%)	
Mean	1.716
Standard Deviation	0.571
Round wood production (thousands meter cube)	
Mean	1.345.471
Standard Deviation	2.819.476
Oil-palm production (thousands tons)	
Mean	942.73
Standard Deviation	1628.56
Coffee production (thousands tons)	
Mean	22.25
Standard Deviation	32.38
Coconut production (thousands tons)	
Mean	92.95
Standard Deviation	92.15
Rubber production (thousands tons)	
Mean	101.91
Standard Deviation	185.66
Cacao production	
Mean	21.22
Standard Deviation	35.64
Number of provinces	32
Number of observations	128